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Case studies in the conservation of biodiversity: degradation and threats

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The rating of biodiversity in arid and semiarid regions on the basis of ecological function and genetic traits of adaptation to severe environmental stresses produces significantly higher values, than that based solely on the commonly applied structural criteria of forms of life and levels of organization. The indirect driving forces of biodiversity impoverishment listed in the Global Biodiversity Strategy that are particularly effective in arid and semi-arid regions are (a) population growth, (b) economic systems and policies that fail to value the environment and its natural resources; (c) inequity in the ownership, management and flow of benefits from both the use and conservation of biological resources; and (d) weakness in legal and institutional systems. The most effective direct human impacts are (a) habitat destruction and fragmentation, (b) overexploitation of biological resources, (c) biological invasion, and (d) agriculture. The problem in arid and semiarid regions, particularly in developing countries, is exacerbated by the lack of knowledge and awareness, the paucity of research, and the diminishing number of competent systematists.

This paper discusses the theoretical and practical aspects of each of the indirect driving forces, and the direct human impacts on biodiversity, and reviews case studies related to these impacts, with special reference to those carried out in arid and semiarid regions. These studies include monitoring of the human impact on land cover by remote sensing, effects of landuse on species diversity, impact of habitat fragmentation by summer resorts on coastal dunes, consequences of protection from grazing on biodiversity, comparison of biodiversity in nature reserves and the traditional *hema* system with that of nearby territories, and the impact of desertification on animal life and endangered species. Case studies also include the tools applied for biodiversity conservation in arid and semiarid lands with special emphasis on endangered species, restoration of degraded habitats and their biodiversity, the significance of nature reserves and captive breeding, the importance of conserving the populations below the species level throughout their geographical range of distribution, and ecotonal biodiversity.

Keywords: biodiversity ratings; degraded habitat; impact; arid land; semi-arid land

Introduction

UNEP (1992) defines three categories of arid zones: hyper-arid (extreme desert), arid (desert), and semi-arid (semi-desert), which occupy 7·5, 12·1 and 17·7% of the Earth's

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surface respectively. The 1980 records of land use show the following proportions of use: 41% nomadic pastoralism; 25% ranching; 12% rain-fed agriculture; 3% hunting, fishing and gathering; and 2% irrigated agriculture; while 16% is either unused or occupied by rural and urban establishments. The arid and semi-arid regions of the Middle East in particular have two features relevant to the issues of biological diversity: they have been inhabited by active human assemblages for millennia, and they are the native habitat of plant species that are parents and relatives of several food and feed crop plants and of hundreds of species that are traditional drug plants (Kassas, 1996). Indigenous animal species bear valuable genetic material. The region is also the geographic transit between the warm tropics in the south and the temperate north not only for migratory birds but also for all aspects of biogeography.

The present landscape in arid regions differs considerably from that of antiquity, when there were extensive forests and a far more closed plant cover in general. Little remains of the original vegetation, and the impression of desert is strong, particularly in the Middle East. Today, barren mountains and a landscape with few forests characterize large areas, in contrast to descriptions of the forests of antiquity, consisting of *Quercus ilex*, *Cedrus libani*, *Pinus halepensis*, *Pinus pinea*, *Pinus nigra*, *Tetraclinus articulata*, *Juniperus phoenicia*, and *Juniperus oxycedrus* (Steen, 1999).

The *Global Biodiversity Strategy* (WRI, IUCN, & UNEP, 1992) considers that the root of the global biodiversity crisis in all ecosystems, including those of arid regions, lies in (a) burgeoning numbers and inappropriate social structures, (b) the way in which man has appropriated ever more of the Earth's biological productivity, (c) the unsustainable consumption patterns of natural resources, (d) global trade and a continuing reduction in the number of traded products from agriculture and fisheries, (e) economic systems and policies that fail to set a proper value on the environment and natural resources, (f) inequity in the ownership, management and flow of benefits from both the use and conservation of biological resources, and (g) weaknesses in legal and institutional systems. These indirect mechanisms have driven direct human impacts, including (a) habitat loss and fragmentation, (b) invasion by introduced species, (c) the overexploitation of living resources, (d) pollution, (e) domestication and selection, (f) global climate change, and (g) agriculture and forestry (McNeely *et al.*, 1995).

Rating of biodiversity in arid regions

Biodiversity in arid regions is often rated as poor and less valuable than biodiversity in other biogeographic regions, based on the commonly applied structural criteria of forms of life (i.e. plants, animals and microorganisms) and levels of organization (i.e. genes, species, and ecosystems). This definition of biodiversity emphasizes structure, although it does not follow that any one number of species or biomass conveys on an ecosystem more value than any other, or that the values of species can be ranked on strictly taxonomic grounds. Carleton-Ray (1988) provides an example of filter feeders, especially zooplankton. These create additional levels in aquatic food chains that do not exist on land. In the oceans, there is also much greater diversity in body size than on land from picoplankton to whales and much larger ranges of ecological time-space relationships. Consequently, aquatic food webs tend to be more complex than terrestrial ones and have more trophic levels.

Therefore, simply knowing which environments have more or fewer species may be misleading and must be subject to further interpretation. Wilson (1988) recommends the examination of life forms, that is, distinguishing species by describing what they do, instead of indicating what they are; this approach gathers life into functional ecological groupings not necessarily related to their taxonomy. For an ecologist, other dimensions of biodiversity are represented by the number of guilds, the variety of life cycles, and the diversity of biological resources. For example, animal species with complex lifecycles contribute extra biological diversity to a site. Therefore, simpler, objective ways of assessing where high biodiversity occurs need to be sought (Harper & Hawksworth, 1996). Real situations will obviously involve many important considerations, including measures of the relative values of species (for example, in arid ecosystems, species preserving 'ecosystem services', or those possessing unusual behavioral or ecological properties, or acquiring unique genetic traits of adaptation to severe environmental stresses). Thus, any assessment and quantification of biological diversity in arid lands needs to go beyond mere species counting and move towards developing a 'calculus of diversity'. In this respect, Faith & Walker (1996) call for best possible use of surrogate information in the practical evaluation of the relative biodiversity represented by different areas. One standard approach is based on 'indicator groups of taxa'.

Root Causes and Main Threats

Three of the root causes of biodiversity impoverishment may be considered of greater impact than others in arid regions and will be dealt with by this review. These are population growth, inequity, and inadequate economic policies and institutional systems. In addition, four main direct threats are considered: habitat degradation and fragmentation, overexploitation of biological resources, introduction of alien species, and agricultural practices.

Population growth

Noin & Clarke (1998*a*) provide an overall estimate for 1994 of the populations in arid and semiarid zones of 841 million (15% of the world population). The semi-arid zone (nearly one-half of the area of the arid world) contains nearly three-quarters of this population, while the arid zone occupies nearly one-third of the area, but has just over one-quarter of the population. In the 20 countries situated entirely or almost entirely in the arid world, the population has multiplied six times since the beginning of the century. This population pressure has had serious impacts on the fragile ecosystems and biological resources of arid zones especially in the Old World. For example, demographic growth in Central Sudan was 2·7% per annum during 1956–93 and 3·1% during 1983–93; while in Syria it was as high as 3·6% in the early 1990s. Jordan has one of the highest growth rates in the world, 4·4% during 1952–79 and 4·6% during 1979–94, as the country has welcomed many refugees. Besides, modern technology is, slowly but consistently, diffusing the hearts of the deserts, changing population-diversity interrelationships. For example, tractors, which ease the physical effort of people and animals, sometimes have clearly negative effects on the soil, and lead to the extension of dry farming into excessively dry areas with limited vegetation cover, as in the badia of Syria, Jordan, and Iraq. Also, the use of the lorries enables the extension of rangeland for sheep to include more fragile ecosystems, and the extension of areas of firewood collection.

Inequity

Another stress on biodiversity comes from the way international trade, debt and technology transfer policies and practices foster inequities that resemble, and often reinforce, those found within nations (WRI, IUCN, & UNEP, 1992). Degradation of biodiversity at local levels in arid lands, particularly in the Middle East, is becoming more and more affected by what is happening elsewhere in the region and beyond.

The process of globalization is affecting the deserts through trade, mining, oil exploitation, remittances and international tourism (Noin & Clarke, 1998*b*).

At local levels, tremendous inequalities in power relations exist among the peoples, and between them and the governments of the countries in which they reside. A serious problem arises in many arid countries from the concentration of resource control and responsibility for environmental policy decisions primarily in the hands of urban men. Ownership and control of land and biotic resources, and all the benefits they confer, are distributed in ways that work against biodiversity conservation and sustainable living. Rapid depletion of species and the destruction of habitats are the norms in these countries. In fact, policy formulation needs to be more sensitive to the most vulnerable population groups (politically and spatially marginal minorities, and economically marginal producers) (Findlay, 1998). Besides, conservation of biodiversity must ultimately be carried out where people live and work; and local communities must have the incentives, the capacities, and the intention to manage biodiversity sustainably. They should receive a fair share of the benefits and assume a greater role in managing their biotic resources. Land-tenure systems and skewed distributions of land ownership, which pose almost insuperable barriers to conservation, should be changed (WRI, IUCN, & UNEP 1992).

Economic policies and institutional systems

One main difficulty facing decision-makers concerned with developing appropriate demographic and environmental policies for an arid region is the absence of any agreed theoretical framework for handling population-biodiversity interactions. As a result, discussions about population in relation to development strategies often occur in the absence of any consideration of biodiversity issues, with debate being constrained to socioeconomic and political dimensions. Findlay (1998) calls for further research on populations in arid regions in order to reduce this considerable difficulty which surrounds much of the policy-making in this topic. Another related difficulty is that most arid countries lack an adequate system of environmental laws and other instruments to ensure the protection of biodiversity and the sustainable use of resources. Largely because of that, biodiversity conservation has typically been piecemeal and concentrated on traditional wildlife protection techniques (a protected area here, a regime for managing an endangered or threatened species there). Such efforts seldom fulfill species' habitat requirements, particularly those of migratory animals (WRI, IUCN, & UNEP, 1992).

These difficulties are augmented in most of the concerned institutions of arid regions by deficient education, and lack of integrated research on natural ecosystems and their innumerable components. Even where these exist, knowledge does not flow efficiently either to decision-makers, which have as a consequence often failed to develop policies that reflect the scientific, economic, social and ethical values of biodiversity; or to the local communities who depend directly on biological resources, and who may have their livelihood jeopardized by inappropriate development projects and other actions. Besides, developing countries of arid regions, where biodiversity losses are high, suffer from the lack of committed, skilled experts in the biological and social sciences, economics, law, policy analysis, ethics and community organizations. In general, Wilson (1988) refers to the low number of professional systematists in the world (less than 1500) who are competent to deal with millions of species; their number may be dropping due to decreased professional opportunities, reduced funding of research, and the assignment of higher priority to other disciplines. This problem is exacerbated in developing countries, particularly in arid regions, where only about 6% of practicing taxonomists (professional and serious amateurs) are based (Gaston & May, 1992, as quoted by May, 1996).

Habitat degradation and fragmentation

The impact of man on habitats ranges from habitat destruction (loss) to habitat degradation and habitat fragmentation. Habitat destruction is widely considered the most pervasive anthropogenic cause of the loss of biodiversity (Myers, 1988). This occurs when the changes to the habitat are so profound and so many species, particularly the dominant ones, are lost that the habitat is converted to another type. Extensive wood-cutting and draining of wetlands in many of the arid regions are two of the main processes that destroy habitats, but regardless of the context in which the consequences are assessed, habitat destruction is the key ultimate cause of the high rate of extinction, and has been a major proximate cause of the loss of biodiversity. Surprisingly, little accurate information on habitat loss is available globally, and the problem is especially difficult to assess in the developing countries of arid regions due to inadequate ground-truthing, less comprehensive monitoring coverage, and difficulty in identifying taxa.

Habitat degradation is the process by which habitat quality for a given species is diminished. Conceivably, habitat quality is a less extreme environmental change than complete loss of habitat. Ideally, habitat quality would be estimated using parameters that are closely tied to population viability and evolutionary fitness, such as reproductive rate and survivorship. In general, however, individuals of long-lived species that remain alive in disturbed and fragmented habitats can be considered 'the living dead' (Primack, 1998); individuals may persist for many years but will eventually die out due to lack of reproduction.

It is likely that changes occur in habitat quality due to climate change. Many species will not be able to redistribute themselves fast enough to keep up with projected climate change, and considerable alterations in ecosystem structure and functions are likely (McNeely *et al.*, 1995). Many of the world"s islands would be completely submerged by the more extreme projections of sea level rise. In this respect, it would be interesting to consider the impact on mangrove ecosystems which are common in some arid countries of the Middle East (i.e. in Saudi Arabia, the Gulf States, Egypt and the Sudan). Ellison (1996) considers that the expected impacts are sea-level rise (primarily through altered sediment budgets), changes in precipitation, temperature rise, and higher levels of atmospheric carbon dioxide. The mangrove of low oceanic islands are likely to be the most sensitive due to low sedimentation rates. Sea-level rise may also cause erosion of sediments at the seaward edge, and increased inundation and salinity may cause stress symptoms in mangrove species, such as reduced litter production and reduced resistance to pests and storms. On the other hand, rises in temperature and increased CO_2 levels are likely to increase mangrove productivity, change phenological patterns, and expand the ranges of mangroves into higher latitudes.

Assessments and monitoring of habitat degradation and its impact on biodiversity in arid regions are rare. Case studies dealing with these subjects have been carried out in the western Mediterranean region of Egypt. Salem (1993) compared the results of satellite imagery from 1978, 1987 and 1990, and found that 6·9% of the land was degraded; the study concluded that if degradation at such a rate persists, complete degradation would cover all rangelands and dry farming areas in 15 years. Salem & Ayyad (1994) also compared the percentage of cover in the same region and found that cultivated areas in general had decreased further in 1992, and that 100 ha of productive land had been transformed into urban area. The effect of several land-use practices (i.e. summer resorts, irrigated agriculture, rain-fed agriculture, local industries and grazing) on species diversity in the western Mediterranean region of Egypt was assessed by Ayyad & Fakhry (1996). The general trend of the effect of resorts on active coastal dunes was a decrease in species diversity ($H' = 0{\cdot}19$ and $0{\cdot}25$) in the disturbed sites as compared to the undisturbed sites ($H' = 0{\cdot}51$). Species that persisted were *Ammophila arenaria* and *Lotus polyphyllos*. On the more stabilized dunes, the general trend was also a remarkable decrease in species richness and diversity in the disturbed sites, where no annuals were detected. Regardless of the type of cultivation, the weed community of rain-fed fields was more rich ($H' = 2{\cdot}16$) than that of irrigated fields ($H' = 1{\cdot}35$). In general, the weed communities of both the irrigated and rain-fed cultivations were less diverse than the 'natural' communities. Only three species out of six could resist the high level of disturbance created by a cement factory: *Arthrocenemum glaucum*, *Atriplex halimus*, and *Suaeda vera*. One important species, *Alhagi maurorum* was completely missing in the polluted sites.

Some desert ecosystems have been shaped by human-induced fires. Burrows & Christensen (1991) indicated that the relatively high plant diversity in the Australian desert was due largely to the activities of aborigines who used fire excessively for many purposes. After the departure of aborigines to settlements and the decrease of fires, plant biodiversity has declined substantially.

Grassland in semi-arid regions has been desertified under excessive human pressure. The 1977 UN Conference on Desertification indicated that, in general, 6% of the world's area is 'man-made desert', and 25% is threatened by desertification. The annual degradation of land to 'desert-like' conditions is estimated by UNEP (1992) as 60,000 km^2. Mackinon & Mackinon (1986) indicate that 65% of the original ecosystems south of the Sahara have been subject to major ecological disturbance.

Dregne & Chou (1992) estimate that 70% of the land (921 million ha) in the Arab countries, is moderately desertified. Of the rangelands, which represent 42% of the total area, 330 million ha are either severely or very severely desertified, and 150 million ha are moderately desertified. The overall proportion of desertification is more than 80% of these rangelands, while in the rain-fed agricultural land, it is 67%, and in irrigated agricultural land, 34%. These high percentages of desertification give an impression of the severe deterioration of biodiversity in the arid regions of the Arab countries, and the extinction of many plant and animal species. But, little information is available on the relationship between the degradation of these drylands and loss of biodiversity. However, it is well known that many species found in deserts are highly endangered: desert tortoises, Asian and African wild asses, sundry species of cactus, and a variety of antelopes such as the addax, scimitar-horned oryx and the Arabian oryx, to name some of the better-known endangered taxa (Hunter, 1996).

Pollutants stress ecosystems and may reduce or eliminate populations of sensitive species. The intensive use of chemical fertilizers has been dramatic. Nitrates seep into groundwater aquifers, and lead to the eutrophication of lakes, rivers and coastal ecosystems, often causing drastic changes in the fauna and flora (McNeely *et al.*, 1995). Many marine species have been locally extirpated by pollution: coral reefs are smothered in silt and shaded by silt-laden water. The equilibrium of marine food webs can be upset (for example, when an excess of nutrients causes the explosive growth of plankton known as the red tide). Water pollution can simply stress populations, reducing their viability by killing individuals (e.g. dramatic oil spills during the Gulf War), or reducing their reproductive success. However, accounts of the negative effects of pollutants typically focus on species that are most liked by humans (birds and mammals), and mankind tends to be more concerned about their welfare; besides, toxic effects on these species may portend toxic effects on humans (Hunter, 1996).

River systems and their riparian zones are especially important in the regulation and maintenance of biodiversity, playing a fundamental role in the movement of organisms and their nutrients. These habitats have significant ecological interactions with the sea, the atmosphere, and the terrestrial surroundings of the river (Naiman, 1992). Damming streams and rivers (e.g. the Aswan High Dam on the Nile) has seriously affected many aquatic ecosystems, flooding ecosystems upstream of the dam and changing water flows to ecosystem downstream of the dam. Many animals move up and down rivers during the course of a year, or during their life cycle, searching for the best places for forage or breeding, and dams can be very significant barriers. The reservoir behind a dam may also impede movement, especially if it has been stocked with exotic, predatory fish. Fish are the main victims of dams, especially anadromous fish as salmon that move long distances between riverine spawning areas and marine foraging areas. Some salmon populations have been completely eliminated, largely by dams. Dyensius & Nilsson (1994) summarize the major effects of damming rivers on biodiversity: the habitat for organisms adapted to natural discharge and seasonal water level regimes are impoverished; the role of each river as a corridor is reduced; and the riparian zone is no longer able to serve effectively as a filter between upland and aquatic systems. In brief, it is well documented that many types of riverine ecosystems have been degraded or lost, and that populations of many riverine species have become highly fragmented, possibly with profound implications on biodiversity.

Wetlands are often keystone ecosystems, playing critical roles in a landscape through hydrological processes, biomass production and export, and removal of contaminants from polluted water. The modification and loss of wetlands has become a major concern of conservationists for the following reasons: (a) the rarity of wetlands; (b) the ecological value of wetlands (c) the role of wetlands as habitats for diverse biota; (d) the facultative use of wetlands by many terrestrial species; (e) the particular value of wetlands as refugia for terrestrial species that are sensitive to human interference; (f) the importance of wetlands as bird areas; and (g) there are many thousands of species that are uniquely adapted to the interference of wet and dry environments (Hunter, 1996). All this makes it imperative to protect remaining wetlands, given the goal of protecting their biodiversity.

Coral reefs are another highly diverse wetland ecosystem type that has been profoundly influenced by human activity. They are declining so rapidly, particularly in the Middle East, that localized exterminations are probable. The major threats to reefs come from anthropogenic pollution, sedimentation, and overexploitation, all of which are increasing with increasing human economic activity.

Habitat fragmentation is the process by which a natural landscape is broken up into small parcels of natural ecosystems isolated from one another in a matrix of other ecosystems, usually dominated by human activities. Hunter (1996) lists the following reasons for the diminishing of biodiversity by habitat fragmentation: (a) small patches have less environmental heterogeneity than large patches; (b) some area-sensitive species and uncommon species are unlikely to be found in small patches; (c) small patches have small populations that are more vulnerable to local extinction; (d) immigration of populations occupying isolated patches is limited; (e) isolated patches are less likely to be used by species that routinely travel among patches; and (f) fragmentation creates more edge zones representing degraded habitat for many species. With decreasing fragment size, more of the habitat becomes affected by the edge of the habitat fragment. For instance, generalist predators invading the fragment from outside often impose an increasingly heavy mortality with decreasing fragment size of the habitat of specialist prey species. Fine-scale habitat fragmentation may disrupt the usual foraging and breeding behavior of species that have evolved to live in more continuous habitats, and thereby the population growth rate may be lowered (Barbault & Sastrapradja, 1995). Assessments of these impacts of habitat fragmentation are lacking in arid zones, although it is conceivable that they may be particularly effective where the vegetation is sparse or contracted.

Overexploitation of biological resources

Exploitation of wild plants and animals is a fundamental human activity, and it becomes overexploitation when the use of populations seriously threatens their viability. The worst situations involve commercial exploitation, particularly because the markets demand for wild organisms is enormous, and the rarer a species becomes the more it is worth (Hunter, 1996). Overexploitation also can result from incidental exploitation and recreational exploitation (e.g. hunting in the Arabian desert). Besides reducing population size, overexploitation can also have deleterious effects on the age, sex, and genetic structure of populations, and, when directed against keystone or dominant species, it can negatively affect whole ecosystems.

In arid regions, the extraction of elements (such as fuel wood) by local communities has crossed the limit of the carrying capacity of the ecosystem. Fuel wood shortage is affecting 2 billion people worldwide, and almost 1·3 billion are consuming fuel wood faster than it is being replenished (McNeely *et al.*, 1995). In addition, urban and industrial demand for fuel wood and charcoal in arid regions has become a major factor in biodiversity degradation, as their utilization has been greatly enhanced by modern facilities for lorries and paved highways.

Overgrazing is also seriously affecting biodiversity in arid ecosystems. It indirectly affects invertebrate species, which often play an important role in the maintenance and stability in ecosystems. Assessments of the effect of wood-cutting and overgrazing in arid regions have been made by a good number of case studies. The effect of protection as an indication of the impact of overgrazing on the plant biodiversity in the western Mediterranean region of Egypt was assessed by Ayyad & El-Kadi (1982) and Ayyad & Fakhry (1996) in plots of different grazing treatments: (a) free grazing; (b) protected grazing; and (c) controlled grazing plots. Under all circumstances, species richness increased in protected and controlled grazing. The most obvious observation was that *Launaea resedifolla*, which could scarcely be recorded before protection, attained higher relative abundance and added to the species richness. Diversity, as measured by the Shannon index, as well as the number of equally abundant species also increased. Similar results were recorded by Halwagy (1962) at Omdurman in the Sudan, and Hamouda (as quoted by Kassas, 1970) at Ras El-Hikma (Egypt). In Mauritania, Adam (1968) reported briefly on several exclosure experiments, and stated that spectacular results had been obtained: trees and shrubs that were previously cut and browsed had come back; grasses and herbs had developed.

The vegetation outside and inside three *hemas* (traditional, protected areas): Hema Bani Sar, Hema Thamala, and Hema Sakhayet, in Saudi Arabia, was compared by Zahran & Younes (1990) in order to assess the effect of overgrazing on plant biodiversity. Inside the *hemas*, the soil was deeper, the organic matter content and cation exchange capacity were higher, the gravel content was lower and the texture was finer. In Hema Bani Sar where grazing was strictly prohibited, the density of the dominant grass *Themeda triandra* was greater, and the palatable species *Linaria haeleva* was common. Outside the *hema*, *Psiadia arabica* (non-palatable) predominated, and *Themeda triandra* was severely grazed. Similarly, Shaltout *et al.* (1996) examined the effect of protection for 14 years against grazing and human impacts of the coastal lowland vegetation in eastern Saudi Arabia. The protection increased species diversity in terms of richness and evenness. Many of the species found to be significantly more abundant inside than outside the protected site were important forage and/or fuel plants including *Anabasis setifera*, *Centaurea pseudosinica*, *Cornulaca monacantha*, *Traganum nundatum*, *Schismus barbatus*, *Salsola vermiculata*, *Calligonum comosum* and *Panicum turgidum*. On the other hand, those species significantly more abundant outside than inside the protected site were either halophyte (*Frankenia pulverulenta*) or weeds of disturbed habitats (*Kochia indica*). The species that were found only inside the protected site and had effective contributions to the total cover (*Rhanterium epaposum*, *Ochradenus baccatus*, and *Lasiurus hirsutus*) were also important for grazing and/or as fuel plants. The species that occurred only in the free grazing area were of a minor functional role from the dominance viewpoint; some of them may be considered as indicators of soil salinity (*Cressa cretica*), weeds of disturbed habitats (*Senecio glaucus, Rheichardia tingitana* and *Phalaris minor*) or neophytes (*Agriophyllum montasiru*).

The loss of biodiversity in aquatic ecosystems can be attributed to mortality due to predation, starvation, disease and fishing (human harvest). Overharvesting of fish can have profound systematic effects. Heavy exploitation of selected species in multispecies ecosystems will influence the balance among competitors and their predators, prey and parasites, changing the dynamics of the system (Beverton, 1990). Stock depletion does not necessarily lead to the endangerment or extinction of species, although it has other undesirable effects (social and economic). Five categories of fisheries are identified (McNeely *et al.*, 1995): (a) traditional or subsistence; (b) recreational; (c) small-scale or artisanal conducted on a commercial basis; (d) large-scale or industrial; and (e) aquaculture. In the third category the pressure on the resources is very great, and fishers are led to use destructive fishing methods such as explosives or poisons which destroy the resource base. Besides, the artisanal multispecies fisheries, can continue to operate after the most desirable species have been drastically reduced in abundance or extinguished locally. In the fourth category, industrial fishing, several factors combine to ensure that most important fish stocks have been fished beyond sustainable levels. Besides, indiscriminate methods leading to high catch mortality can endanger species other than the targeted.

Hunting has exterminated many species, particularly on islands. Prehistoric humans were instrumental in the disappearance of many large mammals in the Americas, the Mediterranean, Madagascar and Australia. However, the use of modern means of hunting, including machine guns and four-wheel drive vehicles in arid lands, particularly in the deserts of the Middle East, have caused widespread extermination of many wild species, among which are endemics.

Introduction of alien species

Another threat to biodiversity is interaction with alien species. Isolation has been a critical factor in shaping the evolution and distribution of species, but human activities have often broken down the barrier of isolation, allowing exotic species to occupy areas outside of their natural geographic ranges (Hunter, 1996). These may invade native communities and ecosystems. In general, biological invasions cause frequent and important prejudice to the integrity of communities, and in the long term, can lead to a decrease in specific variety.

Levin (1989) categorized the introduced species into (a) accidentally introduced, (b) species imported for a limited purpose from which they later escape, and (c) deliberately introduced. Undoubtedly, species introductions are an essential part of human welfare in virtually all parts of the world. Further, maintaining the health of those introduced species of undoubted benefit to humans may require the introduction of additional species for use in biological control programs which import natural enemies of, for example, agricultural pests (McNeely *et al.*, 1995). But, despite some positive effects at the local level, overwhelming evidence indicates negative effects on biological communities, species and genetic diversity at both the local and global level, by predation, competition, disease, parasitism and hybridization. Globally almost 20% of the vertebrates thought to be in danger of extinction are threatened by invasive species, and their spread may be considered as second only to habitat destruction in harming biodiversity (Barbault & Sastrapradja, 1995). The global effects of certain invasive species such as rats, *Ratus* spp., also attest to their widespread effects. A famous example in Egypt is the effects of the introduction of water hyacinth, *Echhornia crassipes,* on the life in the River Nile and the network of irrigation and drainage canals throughout the country. In some sites, it displaced native species, impeded water flow, inhibited penetration of light, increased evapotranspiration and altered water chemistry to such an extent that the water body could no longer support a functioning aquatic community. A more recent example in Egypt is the introduction of the water fern *Azolla ficiculoides* to be used as a biological fertilizer in rice fields, but it advertently has escaped into water courses where it seems to be wiping out a number of other native hydrophytes (e.g. *Lemna* spp. and *Spirodela* spp.). Similarly, an exotic species of freshwater crabs was introduced in aquaculture basins, but it found its way into major water channels where it became a serious pest to commercial fish and to biodiversity in general.

Invasive animal species may eliminate native species directly through animal predation or grazing. The global extinction due to invasives have been recorded, and many examples of local eliminations are documented and provide evidence that invasive species may also act in concert to threaten native species. For example, the rabbits (*Orictolagus cuniculatus*) brought by European settlement soon reached plague numbers and contributed to destruction of habitats and vegetation, and foxes (*Vulpes vulpes*) were also able to reach high numbers preying on the rabbit population. This increase in fox population had a considerable impact on other prey items—native mammals, reptiles, frogs, scorpions and large insect species. Similar local elimination by concerted actions of invasive species in arid regions must be occurring, and need careful investigation.

Aqualculture is very promising and is rapidly increasing, but may have problems and conflicts. For instance, a large number of artificially reared fish escape into the wild and can result in the spread of contagious diseases, ecological interference with wild populations and disruption of the genetic structure of wild populations through introgression, genetic drift and unintentional changes in selection regimes. When genetic effects on performance traits have been detected, they appear always to be negative, though the implications of this for biodiversity remain unclear.

In some cases, species introductions can enrich biotic diversity (Di Castri, 1989). Crawley (1989) argues that this enrichment provides little understanding of ecosystem functioning and how the invasions affect it. Some invaders such as the oat (*Avena fatua*) in the Mediterranean region may become the dominant species in the host-region ecosystem. Other invaders are pest species, which may cause economic havoc, but little is known about the effects of these invaders on the ecosystem or on natural communities, and the consequences of invasions on ecosystem function are generally less well studied. However, the invaders are generally considered symptoms of an abused landscape, one that has been disturbed and has generally lost some of its original productive capacity. Important efforts have been made to get a better grasp on biological, ecological, and genetic characteristics of the populations of invasive species, sometimes by comparing them with populations in the area from which they originated. Two more aspects should be considered: the reaction of communities during the invasive phase on the one hand, and the reconstitution of the community after invasion on the other (CNRS, 1998).

Agricultural practices

Agricultural practices in general have three means of impact on biodiversity: (a) on natural ecosystems and their biodiversity elements within or in place of habitats or areas in which they are conducted; (b) on the genetic variability of the cultivated or husbanded species themselves; and (c) through chemical pollution at the level of intraspecies genetic variation. Traditional agriculture has been tremendously successful in enhancing biodiversity. For farmers practicing low-input agriculture, the maintenance of species and genetic diversity in fields is an effective strategy for creating a stable system of conservation. Cultivated crops often intercross with their wild or weedy relatives growing in the field or in nearby fields, resulting in new characteristics (McNeely *et al.*, 1995). Traditional agriculture has been characterized also not only by high intra-species diversity, but also by the use of a wide variety of crop species within the same system. In India, one species of mango has been diversified into over 1000 varieties; and one species of rice has over 50,000 varieties. Moderate levels of human use tend to increase local biodiversity by opening up new niches, providing new food or shelter sites, and diversifying the micro-habitats. Traditional pasturalists have often tended to foster biodiversity in both plants and animals. They have deliberately bred livestock to meet different needs and conditions. For example, at least a dozen breeds of camel are known in the Sudan alone (Köhler-Rollefson, 1993).

On the other hand, overwhelming evidence leads to the conclusion that modern commercial agriculture has had a direct negative impact on biodiversity at all levels: ecosystem, species and genetic; and on both natural and domesticated diversity. On-farm diversity is shrinking fast due to modern plant breeding programs and the resulting productivity gains achieved by planting comparatively fewer varieties of crops that respond better to water, fertilizers and pesticides. Also, modern intensive agriculture has had an adverse impact on the physical environment through the degradation of land and the depletion of water resources. In fact, modern agriculture may be one of the most important causes of pollution by the production of sediments, the generation of chemical wastes or the use of pesticides; and the runoff of organic wastes and inorganic fertilizers inflicts significant damage on aquatic ecosystems (McNeely *et al.*, 1995). In addition, it is estimated that 2 million ha per year are lost through salinization. It is also remarkable that as a result of changing conditions in agricultural fields, many species of wild birds that had adapted to previous environmental conditions are undergoing significant population declines. The loss of genetic diversity also occurs with animal domestication where a few highly productive breeds are transported worldwide displacing and eventually resulting in the extinction of local breeds.

Important conservation issues

Ex situ and in situ conservation

In the conservation of biological diversity in general, the emphasis has been on preservation of what already exists. Preservation obviously has a critical role to play in the conservation of diversity; however, by itself it is not an adequate strategy for conserving biological diversity. Ultimately, there is a need for a way of putting pieces back together when something has been altered, damaged, or even destroyed (Jordan, 1988). In recent decades, some institutions have become directly involved in *ex situ* conservation, specifically maintaining organisms outside of their natural habitat (zoos, aquaria, botanical gardens and by storing seeds, spores, sperms, embryos, and similar material, as well as microorganisms). Rahbek (1993) reviews two examples of *ex situ* conservation: the peregrine falcon (*Falco peregrinus*) program, and the Arabian oryx (*Oryx leucoryx*) program. He concludes that captive breeding programs are very resource-demanding and can only be afforded for a very small number of species, which limits their value significantly. Zoos deal mainly with vertebrates, but these comprise less than 3% of the described species, and they probably only contribute to the conservation of 20 species. The situation for birds, reptiles and amphibians is even worse. Today, when the extinction of species has reached such daunting dimensions, captive breeding and other *ex situ* conservation tools should be the last resort for preserving biodiversity, and captive breeding must not become an excuse to avoid dealing with the preservation of habitats. In addition, *ex situ* conservation programs have to be carefully integrated with *in situ* programs, so that *ex situ* populations can constitute (a) insurance against the loss of natural populations; (b) a direct contribution to the conservation of wild populations through education, research, and funding; and if necessary (c) a source for reintroduction projects (Hunter, 1996).

Choosing specific sites for *in situ* conservation management (reserves) involves the weighing of multiple criteria such as size, representativeness, rarity, condition, and feasibility (Hunter, 1996). In fact, many of the existing reserves in arid regions are often inadequate in size or are suboptimal in shape or design; in many cases, their value as reservoirs of biodiversity could be dramatically increased by relatively modest increases in size. Hanski & Hammond (1995) emphasize a fact that applies well to arid regions, that large reserves may often be needed most for protection of the vast range of small-bodied specialist species which live in (networks of) micro-habitats found only in large, intact stretches of habitat. Also, care must be taken not to focus solely on planning and implementing conservation actions, and thereby neglecting monitoring that can lead to modifications of mankind's actions. Finally, the overriding priority is to try to deal with the root causes of biodiversity loss, rather than the symptoms.

Ecological restoration

The inevitability of further change, including changes in climate, clearly implies that in order to preserve many communities over the long term, mankind has to learn not only how to manage them but even how to move them around. This introduces the area of environmental healing or ecological restoration. A research team in Montpellier (France) has presented a model for the restoration, rehabilitation and reallocation of degraded plant covers in arid and semi-arid lands (Aronson *et al.*, 1993). It contains 18 vital ecosystem attributes for evaluating stages of degradation, and 10 hypotheses concerning ecological restoration, rehabilitation and reallocation. The least damaged ecosystems should be restored. A second category, with greater and to some extent irreversible degradation can only undergo rehabilitation. The worst category has no way back. A new plant cover must be shaped by man; reallocation must take place.

Jordan (1988) reviews the experience of the University of Wisconsin-Madison Arboretum, where research on the restoration of ecological communities native to Wisconsin and the Upper Midwest has been underway since 1934. Intensive restoration has been carried out on several hundred hectares of land, most of which had been seriously degraded by farming, logging, and sporadic development during the preceding century. Gradually 40 hectares of tall-grass prairies have been restored on degraded pasture and plow land. The first lesson that one might derive from this experience is that it is indeed possible, at least under certain circumstances, to re-create reasonably authentic replicas of some native ecological communities. For example, the arboretum's two restored tall-grass prairies now include areas believed to resemble quite closely prairies native to the area—at least with respect to floristic composition.

On the other hand, there are large areas of these prairies where ecological or historic authenticity is relatively low, and where various exotic species are abundant. The problem of dealing with exotics is an ongoing one, and the struggle will in many instances be unending. Undisturbed natural communities are also vulnerable to invasions by exotic species but, in general, probably less so than communities in the process of being restored. Without doubt, this has turned out to be a major problem facing restorationists. In addition, the restoration program at the arboretum has strongly emphasized revegetation, with far less attention being paid to the reintroduction of animal species. A related problem with restored communities generally is their small size, which can directly influence their ecological quality. Certain animals, for example, may not inhabit restored communities simply because these communities are too small. On the positive side, however, the arboretum's restored communities have brought back into the landscape numerous plants and animals that had become rare or been eliminated locally. The entire project certainly represents an enormous contribution to what might be called the native diversity of the Madison area.

Another example of restoring and rehabilitating ecosystems comes from the arid regions, in the Raqqa Province of the Syrian badia. Recently, sites of the province were afforested to restore the old vegetation cover that once distinguished the area. The affrorestation involved plantation of species of economic value such as pine, olive, pistachio, fig, grapevine, and date palm. It led to the regeneration of many perennial shrubs and herbs which were on the verge of extinction due to long-term overgrazing and wood cutting, *Artemisia herba-alba*, *Prosopis stephaniana*, *Salsola vermiculata*, *Hordeum glaucum*, *Ephedra alata*, *Bromus tectorum*, *Rumex*, *roseum*, *Iris sisyrichium*, and *Teucrium polium*. In addition, the construction of a dam on the Euphrates in this region generated a man-made lake, and formulated several small islands. This constituted a wetland attracting a remarkable number of migratory birds such as the grey heron, little egret, rock dove, hooded crow, and robin redbreast, besides many wetland and aquatic plant and animal species.

Restored communities may well have other economic values that have not yet been fully identified or widely recognized. Examples include development of wetlands to control water distribution, to rehabilitate soils degraded by agriculture, and to develop forests for sustained-yield timber production. Applications such as these at least suggest ways in which restoration might eventually prove critical (Jordan, 1988).

Diversity in soil systems

Biodiversity in soil systems has received much less attention, especially in arid lands, than above-soil systems. Nevertheless, the soil system contributes significantly to the total biodiversity; it is inhabited by a great diversity and concentration of soil animals that collaborate in the elaboration, maintenance and evolution of its structure and its characteristics. If the assessments of biodiversity are to advance, soil flora and fauna will be very pertinent to them. This is because they are more sedentary and hence more likely to be collected as a comprehensive biotic component, and are also more likely to reflect environmental conditions not only within the soil but also above it.

Because the soil is a secluded environment, some elements of this component may remain in that medium even after the environmental conditions that favored their life in it have gone, hence, the description of the soil as a 'conservative' environment (Ghabbour, 1996). Soil species are also more numerous and more diverse than above-ground species, and thus offer a much wider range of taxa with high variability and so are more amenable to classification. Their variability goes hand-in-hand with changes in environmental conditions, comprised of variations in both time and space.

During land reclamation for agricultural development in deserts, such as the Mariut region west of Alexandria, drastic changes occur in the diversity of populations of soil species, as the soil environment is transformed from a desert to an agro-ecosystem. Monitoring of these changes and the environmental conditions that favor the appearance of pest species, and may also cause the disappearance of some useful detritivores helpful in the maintenance of biological soil fertility, becomes a very important aspect to be closely watched. Furthermore, study of the diversity of soil populations can be used as a tool for the choice of nature and biosphere reserves, and for the characterization of sites on the basis of environmental criteria.

Although not as numerous as soil protozoans or nematodes, there have been more studies of the species assemblages of soil microarthropods in arid and semiarid regions than of more numerous groups. The microarthropod fauna of desert soils can be very diverse. In comparison with the data available on species diversity in desert soil microarthropods, there are no studies of species diversity of nematodes and protozoans. Cephalopid (bacteriophagous) nematodes are most numerous in the early stages of decomposition and are replaced by the fungivorous and omnivor-predator trophic groups in the later stages of decomposition (Whitford, 1996).

In some ecosystems, termites are sufficiently diverse and abundant to contribute significantly to atmospheric fluxes of carbon dioxide and methane. These functions further emphasize the keystone role that species of termites may play in arid and semiarid ecosystems. Assemblages of ants and termites in arid ecosystems range from less than ten species to more than 100 species per hectare. These organisms are important determinants of the structure and function of arid ecosystems because of their effects on the spatial and temporal distribution of essential resources: water and nutrients.

There are no data on species assemblages of soil protozoans from arid and semiarid soils. Few studies of ecosystem processes in these soils have included protozoans in the measurements. These studies have reported protozoan populations as ciliates, flagellates, and amoebae with no attempt at further taxonomic breakdown.

Few studies have been carried on the soil microflora in arid regions. One example is a study on the influence of different ecological factors on the distribution and abundance of bacteria, actinomycetes and fungi of the root zones of three dominant plant species inhabiting the sand dunes west of Alexandria (Rezk *et al.*, 1985).

Ecotonal biodiversity

Another important issue related to the conservation of biodiversity is ecotonal biodiversity, especially in the transitional zones between terrestrial and aquatic ecosystems. This issue needs to be carefully addressed in arid regions. It has been studied frequently in other biogeographic regions and has been reviewed in connection with land-inland water ecotones (Lachavanne, 1997).

The concept of ecotones was first used in the sense of an environmentally stochastic stress zone, and to denote the junction (transitional) zone between two communities. In this sense, it bears special importance in arid regions where slight environmental incidents entail dramatic changes in the structure, function and dynamics of biological communities. At the landscape level, ecotones can be viewed as zones where spatial and temporal rates of change in an ecosystem's structure and function are rapid relative to the rates across the landscape as a whole (Di Castri & Hansen, 1992). So, ecotones can be viewed as unstable components that are sensitive to frequent stresses.

Because of several processes at work within the ecotone itself and because of its proximity and functional ties to the adjacent ecosystems, biodiversity (i.e., species richness) is relatively high (Risser, 1990). Consequently, ecotones are of major importance in maintaining biodiversity and the global gene pool. In addition, the great variety of living conditions at the varied time and space scales characteristic of ecotones (specially land-water ecotones) develop a broad spectrum of habitats and higher species richness. Therefore, there is an urgent need for the study of ecotone-biodiversity relationships in arid landscapes. In this connection, the Egyptian Environmental Affairs Agency (1998) notes that the occurrence of many plant and animal species in Egypt (and certainly in other countries of the Middle East) is on the very edge of their range of distribution. Under these conditions, such species have limited tolerance for environmental stresses. The best example of this precarious existence is the case of corals in the Red Sea, the Gulf of Suez and the Gulf of Aqaba, localities that represent the northern most latitudinal limit of coral distribution in the world. Any environmental changes in such a fragile ecosystem are bound to initiate a series of negative and destructive impacts on the biodiversity of this ecosystem, and thus call for careful conservation efforts.

Genetic diversity below species level

There has been deep concern about the loss of species, communities and ecosystems, but there is often the tendency to downgrade the importance of the extinction of populations below the species level on the assumption that other populations of the same or similar species can supply the same services. However, the loss of such populations cannot be separated from the loss of higher-order levels, and reduction in the numbers and sizes of such populations may doom a species to extinction long before it becomes scarce in nature (Barbault & Sastrapradja, 1995). In fact, biodiversity conservation starts with knowledge of genetic diversity within and among populations, since biodiversity manifests itself at all levels of the biological hierarchy from genes to ecosystems. Ehrlich & Daily (1993) raise the questions: how would population diversity vary among a species within its range of distribution, and how does population diversity relate to species diversity globally?

To understand extinction processes, population structure, especially, metapopulation structure in which populations are subdivided into semi-isolated subpopulations occupying patches of habitat, needs to be understood. A key question is raised by Hunter (1996) as to whether or not the rate at which new subpopulations are created by colonization exceeds the rate at which existing subpopulations are lost to extinction. This has become a major problem because natural ecosystems have been extensively destroyed and fragmented by human activities. Population viability analysis (PVA) is a process, which uses simulation models to assess the long-term viability of a population, and is based on estimating the probabilities surrounding environmental, demographic and genetic factors that can influence a population's likelihood of persistence. Hunter (1996) characterizes species with high levels of genetic diversity as (a) being better equipped to evolve in response to changing environments; (b) being less likely to suffer a loss of fitness because of the expression of deleterious recessive alleles in homozygous individuals, among other problems; and (c) offering plant and animal breeders greater scope for developing varieties with specific, desirable, traits such as resistance to drought and salinity (as in arid regions), as well as disease, and other stresses. Genetic diversity can be eroded by three phenomena associated with small populations. First, when a population is reduced to a small size (i.e. it passes through a bottleneck), some genetic variance and uncommon alleles are likely to be lost. Second, among small populations, especially those that remain small for multiple generations, random genetic drift changes the frequency of alleles, often reducing genetic diversity, particularly when genes are fixed for a single allele. Finally, inbreeding between closely related individuals can diminish genetic diversity. When estimating the effects of these processes on populations, it is important to estimate the effective population size, which is often substantially less than the actual population size.

Studies on the genetic diversity of plant species in different biogeographic regions of Egypt were carried out for about 20 years to provide a base for assessing these effects. El-Sadek & Ayyad (2000) reviewed these studies and posed the following important conclusions and recommendations:

First, a very important contribution that a program in biological diversity could make would be to develop criteria and methods, including statistical treatments, to analyze diversity at the organismic and population levels.

Second, there is a lot of information on the environment's effects on mutation rates, but what needs further study is how heterozygosity and higher-order diversity affect mutation rates, and the hypothesis that heterozygosity increases the ability of an organism to cope with variable environments needs to be tested.

Third, most studies of genetic diversity are limited to species with in their local distribution. However, it is conceivable that much greater variability exists between the populations of a species in its full range of geographical distribution. Thus, more comprehensive treatments of the genetic diversity of species, international and regional collaborative studies, and cooperation in the collection and exchange of germplasm are needed. Geographical differentiation (the between-population component of genetic variation) is frequently related in an adaptive way to environmental differences (e.g., semiarid to arid and hyperarid climates) across the species range. A conscious effort to include the full range of ecologically relevant variation may increase the chances of preserving the species' full ecological amplitude.

Fourth, intermediate biotypes are usually observed in intermediate ecological niches (e.g., *Urginia maritima* and *Plantago salicifolium* in the Egyptian deserts), and identification of hybrids is still an issue of debate, since specific genetic markers (isozymes, RAPD, RALF and mini-satellite DNA markers) are rarely available.

Fifth, populations of high morphological and genetic uniformity, in spite of inhabiting different habitats, should be listed as endangered populations (as in the case study of *Medicago* populations in arid regions). Efforts should be focused on *in situ* conservation of these populations in view of the fact that they are valuable genetic resources.

Sixth, the following topics need to be focused upon in the future:

(a) Ecological genetic studies in desert ecosystems need to be intensified giving priority to endangered species and/or populations.
(b) Data from such genetic inventories need to be utilized in describing strategies of adaptation and survival, and thus population abilities to survive in heterogeneous environments.
(c) Knowledge of the abundance and distribution of genetic variation among populations for adaptive traits (e.g. drought-resistance in arid regions) is a prerequisite for modeling the response of these populations to environmental changes.
(d) Future population-genetic-diversity studies should utilize probes for known gene content, representing different types of transcribed and non-transcribed sequences, in order to assess genetic variation in different regions of the genome. This calls for a more efficient standardization of methods, particularly with respect to sampling, genetic screening and quantification of genetic variation.

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